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Procedia Engineering 24 (2011) 523 – 527
Procedia Engineering
www.elsevier.com/locate/procedia

2011 International Conference on Advances in Engineering

The Design of ECG Signal Generator using PIC24F

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Abstract

This paper reports a precise design and development for ecg signal generator for testing and calibration of the electrocardiogram equipment, ecg signal processing system and heart teaching tool. It can create a guide Ⅱ signal of time and profile features lead Ⅱ signal across a range of ecg drawings of heart rate within 45 to 185 devices in the first device of steps. This can be set up 15 ~ the QRS 45 years old lady with a lady who resolution. P, T wave amplitude can be adjusted from 1-100% to 1% of the total of the amplitude QRS complex resolution. A color LCD touch screen is able to provide the user with input parameters facilities, depending on the output waveform parameter and a graphical representation of the output waveform. Signal generator outputting signal of poor precision through digital simulation stage using low noise design provides accurate signal amplitude QRS the lower end of the technology range.

Selection and/or peer review under responsibility of ICAE 2011

Keywords: ECG signal generator,PIC241F, timing profile

1. Introduction

The first record of ENTHOVEN the electrocardiogram (ECG) being started in 1904 in the process would see the electrocardiogram become one of the most valuable diagnostic tools in medical function. In this age of complex coronary angiography imaging technology, such kind of technology is used in the diagnosis and treatment of coronary artery disease, and also formed a ECG front tools in coronary care. So to keep records of the wave form and the electrocardiogram through recording equipment is very important.

The growth of plants and usability of ecg record equipment has grown rapidly. The development of portable and compact 3 months and 12 boot record systems by the manufacturer has seen the introduction of modern computer equipment and provided graphical user interface (GUI) and output platform. Electrocardiogram (ecg) record has been expanded to the local surgery, sports medicine and used in

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doi:10.1016/j.proeng.2011.11.2689

portable ecg telemetry. And sex whencg signal records in the treatment of patients with heart disease and the current global economic climate, the necessity of the evaluation found and re-calibrate the fault are widespread electrocardiogram instrument as always. Today many in the industry standard input or design provide all published (in the literature 12) lead electrocardiogram test signal as a patient simulator. Most of these signal generators do not provide all P and amplitude range QRS complex is not less than 100 μ V climb in [1], [2]. Others' design time do not reproduce electrocardiogram accurately, which are based on component model and only estimate time [3].

2. Background

This work is a continuation of the previous design from the suggestions of Burke and Nasor [4]. To finish this work needs to design the user interface, update the system, increase bit of the resolution of the ecg signals obtained and the correct output signal amplitude of the low end of precision output to design digital simulation range conversion (DAC) phase of the generator. The timing of each component of the ECG signal is governed using a series of duration equations suggested by Burke and Nasor. The components as defined in Fig. 1 are a standard method of segmenting the ECG lead II signal. The duration equations were derived by applying a wavelet transform method to identify the onset, peak, termination and duration of each of the individual components of the ECG. Second order equations with square root of the cardiac cycle time TR-R of the form $AT^{1/2}$R-R+ $BT_{R\text{-}R}$+C were fitted to the data to characterize its timing variation.

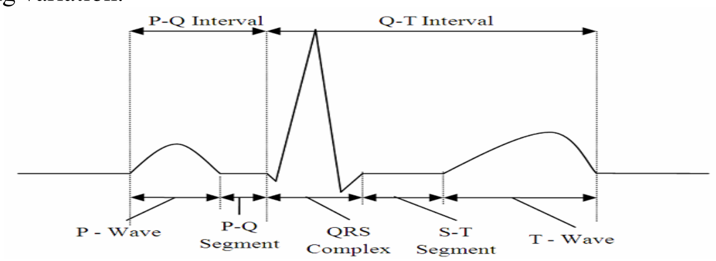

Fig. 1 A typical ECG Lead II with timing of components shown.

A set of equations for combined male and female subjects are:

$$T_{P-Wave} = 0.37T_{TR-R}^{1/2} - 0.22T_{R-R} - 0.06 \quad \text{s} \tag{1}$$

$$T_{P-QSeg} = 0.33T_{TR-R}^{1/2} - 0.18T_{R-R} - 0.08 \quad \text{s} \tag{2}$$

$$T_{P-QInt} = 0.69T_{TR-R}^{1/2} - 0.39T_{R-R} - 0.14 \quad \text{s} \tag{3}$$

$$T_{QRS} = 0.25T_{TR-R}^{1/2} - 0.16T_{R-R} - 0.02 \quad \text{s} \tag{4}$$

$$T_{Q-TInt} = 1.21T_{TR-R}^{1/2} - 0.53T_{R-R} - 0.31 \quad \text{s} \tag{5}$$

$$T_{T-Wave} = 1.06T_{TR-R}^{1/2} - 0.51T_{R-R} - 0.33 \quad \text{s} \tag{6}$$

$$T_{S-TSeg} = -0.09T_{TR-R}^{1/2} + 0.13T_{R-R} + 0.04 \quad \text{s} \tag{7}$$

These equations are used as the basis for providing an ECG profile which alters over varying heart rate with genuine ECG in vivo variation [5].

3. Methodology

The design is based on PIC24 micro controller family. The device provides all the power and flexibility of the advantage and micro controller and provides relevant traditional access and function which often lets a person associate to the faster processor. This device can be in 100-PinTQFP package, including 84 I/O needle, 128 KB of the program memory, 8 k data memory and a port is called a parallel port (PMP) master. The picture displays the mechanism that at any time the PMP is used for liquid crystal displays, USB interface and a wireless network. This makes the signal generator keep users based on the advantage of network and PC related design usually is isolated, but still the battery is relatively cheap and light. This is PIC24F programming development and utilization of this chip explorer 16 development kit, as is shown in Diagram. 2 for the high level structure of the signal generator.

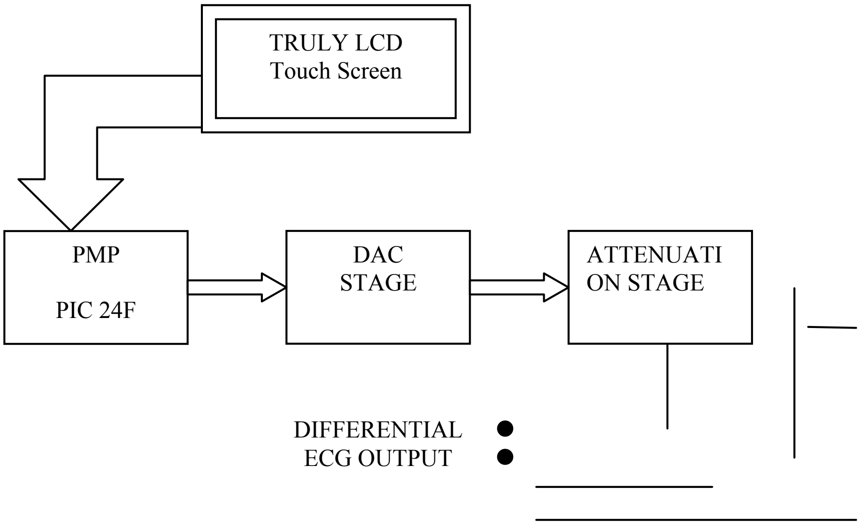

Fig. 2 Block Diagram of the ECG Signal Generator.

4. Software design

The design of software signal generator provides the user with a graphical user interface (GUI) to input the required component parameters and observation results timing parameters, a representation of the guide II signal as it refreshes the LCD screen.

The GUI interface provides a real 320 x240 pixel TFT LCD color touch screen. The real advantage is it supports screen graphics solutions software chip. The software consisting of a number of C languages provides the low level library communication link PIC code LCD and touch screen technology. The library will also assist animation and icon for the operation of the generator.

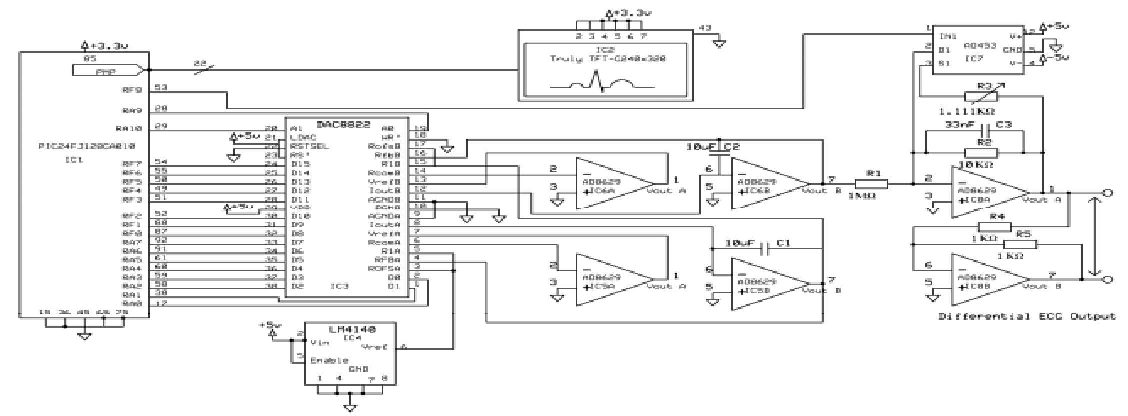

Fig. 4 Schematic Diagram of Signal Generator.

5. Hardware design

Fig. 3 is the schematic diagram of the signal generator. To isolate the device from mains earth the entire system is run on Li-ion batteries. Although not shown in Fig. 4 (to maintain clarity) each device's power connections are de-coupled with the appropriate capacitors.

Speed and noise calculations were carried out to identify the appropriate resolution to generate the ECG with varying degrees of accuracy. It was determined that 14-bit resolution would guarantee a Signal to Quantization Noise Ratio (SQNR) of 90 dB over the full QRS amplitude range. The DAC selection process identified the DAC8822 dual current output 16-bit DAC (IC3) by Texas Instruments as the most appropriate DAC for this application. The DAC provides up to 16-bit resolution (15 data + 1 sign bit), parallel inputs and generates the required QRS ramp from input code 0…000-1…111 (16,384 steps) within the required minimum QRS upslope duration of 15 ms due to its 2 Mega Samples per Second (MSPS) processing speed.

DAC A is used to step down the 2.048 V reference voltage supplied by the LM4140 precision reference voltage chip IC4. The reference is stepped down to the appropriate levels required to generate the QRS, P and T wave amplitudes as per the user inputs. DAC B is then used to receive the digital samples from the PIC and generate the analogue ECG signal.

By test and also communication with DAC suppliers it became evident that a multiplying DAC's performance greatly deteriorates as the required output signal →reduces in amplitude. In fact tests on a number of DACs (DAC8822, AD5547 and AD394) have shown that commercially available DACs are not capable of outputting analog signals at amplitudes lower than 10 mV accurately. Using the DAC to output signals below the 1 mV range and beyond is not recommended by DAC suppliers and under test proved impossible to attain. The authors believe that this is the main source of error in many ECG signal generator designs.

To overcome this problem the ECG signal is output at 100 times the required amplitude to generate mV range QRS amplitude signals and 1000 times the required amplitude to generate μV amplitudes. The signal is then attenuated using a low noise and low offset amplifier circuit to provide the required level.

The attenuation stage requires the use of an inverting amplifier to attenuate the output signals appropriately (IC8A). Operational amplifiers are also required to convert each of the DAC current output signals to voltage signals (IC5B and IC6B), to invert the reference voltage to allow the bi-polar representation of ECG signals (IC5A and IC6A) and to generate the differential output signal (IC8B).

Since the op-amps are passing signals in the order of 10 μV (i.e. the scaled P and T waves) it is imperative that the devices used provide the optimum compromise between noise performance and minimum offset voltage effects. Noise models for the op-amps used in the different applications were created and resulting output noise voltage equations derived. The resulting equations were applied to 16 different devices selected from commercially available low noise op-amps. Equation (8) is an example of the output noise voltage equation derived for the op-amp arrangement around IC8B in Fig 4.

$$V_{no} = \sqrt{Vna^2\left(1+\frac{R5}{R4}\right)^2 + \left(in^2.R5^2\right) + \left(Vres^2\left(1+\frac{R5}{R4}\right)^2\right)} \tag{8}$$

Where:

Vno = total output noise voltage due to all noise sources

Vna = voltage noise for op-amp

in = current noise for op-amp

Vres = resistor noise voltage for R1 and R2

Applied to the parameters of IC8B this yields:

$$V_{no} = \sqrt{243\times10^{-15}V\left(1+\frac{1k\Omega}{1k\Omega}\right)^2+\left(10\times10^{-24}A.1k\Omega^2\right)+\left(4.14\times10^{-15}\left(1+\frac{1k\Omega}{1k\Omega}\right)^2\right)} \quad (8)$$

$$V_{no} = 0.99\mu V$$

The results obtained by using these output noise voltage models indicate that the Analog Devices AD8629 dual op-amp device provides a perfect balance between low voltage offset (1 μV), offset drift (0.005 μV/C°) and very low output noise voltage performance.

IC7 is an analogue switch that is used to alter the attenuation stage between 40 dB and 60 dB by altering the resistance in the feedback loop for IC8A. The capacitor C3 is in place to low pass filter the ECG signal and remove the quantization staircase resulting from the DAC process. The first order filter has a cut-off frequency of 500Hz ensuring the ECG signal spectrum is not filtered or the profile phase distorted.

6. Conclusion

Instrument provides customers with an easy way to use industrial standard color GUI similar to those found in professional biomedical instrument. The unit is not only low cost, accurate and portable but PIC24F choice as a central processor means device which may at any time would be connected to a PC or used for wireless network using PMP and other C library similar chips used in the design of the graphics library.

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